American Journal of Public Health
Official Monthly Publication of the American Public Health Association
Vol. VII MAY, 1917 No. 5

A STATISTICAL STUDY OF DIPHTHERIA.

FREDERICK S. CRUM, PH. D.,
Assistant Statistician, Prudential Insurance Company of America, Newark, N. J.

Read before the Vital Statistics Section, American Public Health Association, Cincinnati, Ohio, October 27, 1916.

STATISTICS of diphtheria and croup are difficult to appraise for various reasons. This disease was for many years confounded with various other diseases, including scarlet fever, and its positive diagnosis in all cases was not possible until Klebs discovered the specific germ in 1883. Then, again, various terms were used more or less interchangeably for diphtheria for a long period previous to 1821 when the term *diphtheria* was first used by Bretonneau. Subsequent to 1821 croup, even of the membranous type, was separately reported in most of the registration offices of the world and this was continued until comparatively recent years.

Diphtheria as a cause of death was first so separately classified by the Registrar-General of England in 1855; it appeared for the first time in the New York City reports in 1857; and in the Massachusetts registration reports in 1858. In the Annual Report of the City Inspector of New York for the year ending December 31, 1860, the statement was made that "It (diphtheria) is not contagious. No reliable evidence has otherwise been given." (p. 244.) In this report the further statement was made that "It serves well as a cloak when the patient died of *croup* or *scarlet fever*, for our *panic-makers* have made the idea general that it is almost positively fatal, in most cases; hence, a death from it is regarded as a forecast result, and no fault is found with the attending physician."

Many experiments with the Klebs-Loeffler bacillus during the period 1883 to 1890, led to the discovery of antitoxin in the latter year, and this discovery led immediately to many controversies over the question of the merits of antitoxin as a curative agent. The use of antitoxin, however, was begun at once, notably in Germany and in New York City, and doubt as to its efficacy was quickly dispelled when the curative results began to be reflected in the decreased mortality among cases treated with the new remedy.

Because of the recent improvements in laboratory practice and the rapid extension of the application of scientific methods to the diagnosis of diphtheria it is quite impossible to compare the diphtheria morbidity rates of recent years with the morbidity rates of the pre-antitoxin or early antitoxin periods. In the comparative death-rates of this disease, however, we are on safer ground, for the cases of diphtheria and membranous croup which terminate fatally are more likely to be correctly certified than mild cases are likely to be correctly diagnosed.

In the years immediately subsequent to the discovery of antitoxin there was a lively controversy waged between those favoring and those opposed to its use. Today there are few physicians who would be bold enough openly to proclaim their opposition to the use of antitoxin, for such an expression of opinion would be a bad advertisement in any enlightened community. All diphtheria mortality statistics clearly indicate a decline in the mortality from this disease immediately after the use of antitoxin has become extensive in any given locality, city or country.

In Table 1 the comparative mortality from diphtheria and croup in pre-antitoxin and recent antitoxin periods is exhibited for twenty countries, in most of which the registration of vital statistics has presumably been fairly efficient throughout the periods to which the data relate.*

According to this table the average annual death-rate in the twenty countries combined was 16.3 per 100,000 of population during the antitoxin period,

*See also Chart I, p. 447.

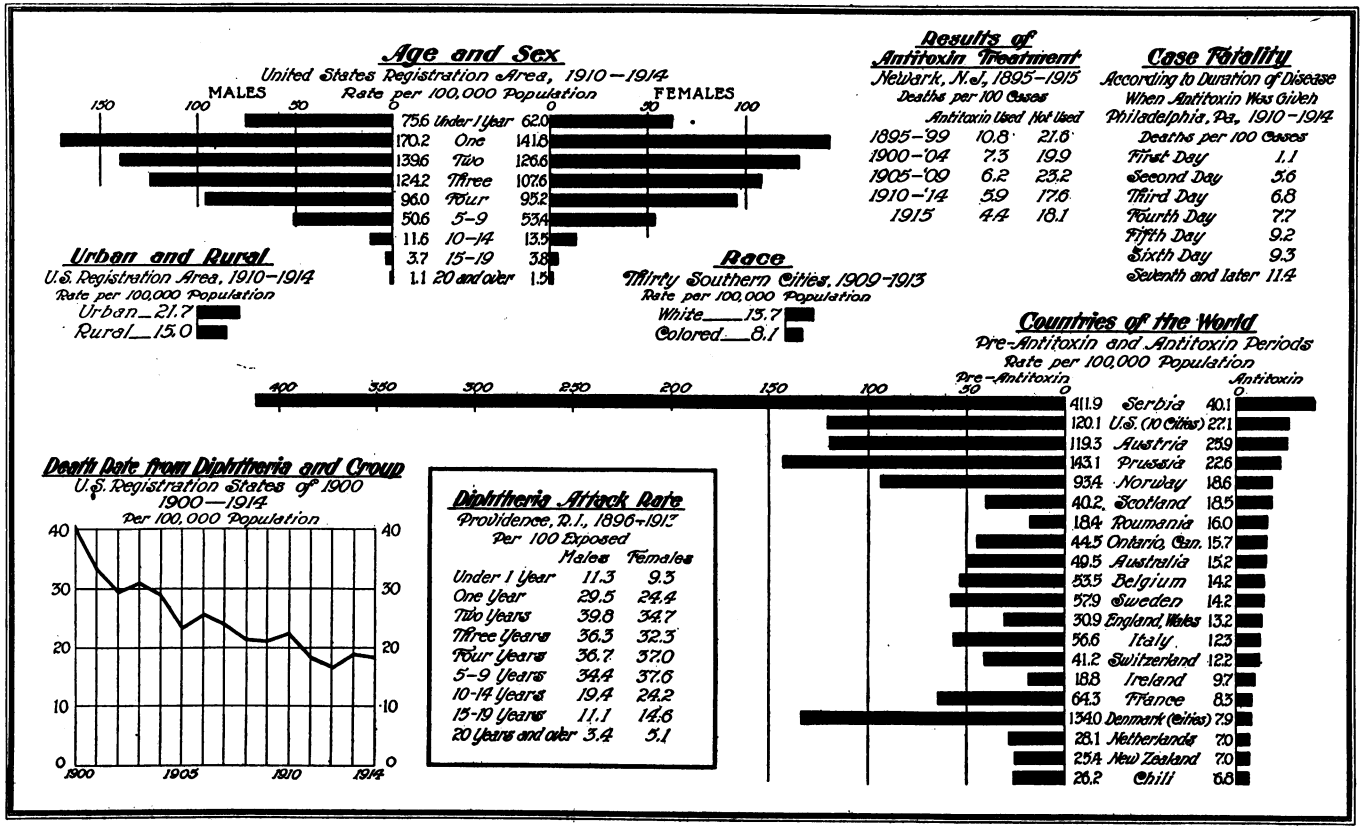
TABLE 1. MORTALITY FROM DIPHTHERIA AND CROUP IN TWENTY COUNTRIES.

Country.	Pre-Antitoxin Period.				Antitoxin Period.				Mortality Reduction.	
	Years.	Population.	Deaths.	Rate per 100,000 population.	Years.	Population.	Deaths.	Rate per 100,000 population.	Decrease in the rate.	Estimate of lives saved yearly.
Serbia	1892-96	11,383,189	46,891	411.9	1907-11	14,319,158	5,747	40.1	371.8	10,648
Ten cities of the United States	1889-93	34,048,719	40,877	120.1	1910-14	62,137,543	16,839	27.1	93.0	11,558
Austria	1889-93	119,900,414	143,090	119.3	1908-12	142,091,028	36,839	25.9	93.4	26,543
Prussia	1889-93	150,981,087	216,073	143.1	1909-13	202,402,338	45,723	22.6	120.5	48,779
Norway	1889-93	9,979,100	9,322	93.4	1909-13	11,872,500	2,210	18.6	74.8	1,776
Scotland	1889-93	20,213,621	8,120	40.2	1910-14	23,706,119	4,389	18.5	21.7	1,029
Roumania	1889-93	26,877,394	4,952	18.4	1910-14	36,340,027	5,799	16.0	2.4	174
Ontario	1889-93	10,747,138	4,778	44.5	1910-14	12,772,835	2,011	15.7	28.8	736
Australia	1889-93	15,932,362	7,889	49.5	1910-14	23,228,258	3,529	15.2	34.3	1,593
Belgium	1889-93	30,757,190	16,470	53.5	1908-12	37,323,929	5,307	14.2	39.3	2,934
Sweden	1889-93	23,955,210	13,860	57.9	1907-11	27,255,585	3,857	14.2	43.7	2,382
England and Wales	1889-93	145,479,965	44,933	30.9	1910-14	181,930,953	24,097	13.2	17.7	6,440
Italy	1889-93	152,276,502	86,138	56.6	1909-13	173,569,932	21,415	12.3	44.3	15,378
Switzerland	1889-93	14,897,082	6,131	41.2	1909-13	18,915,843	2,301	12.2	29.0	1,097
Ireland	1892-96	22,932,527	4,314	18.8	1910-14	21,914,149	2,117	9.7	9.1	399
France	1889-93	50,451,824	32,460*	64.3	1907-11	197,206,000	16,279	8.3	56.0	22,087
Denmark†	1890-94	3,843,185	5,151	134.0	1910-14	5,690,580	447	7.9	126.1	1,435
The Netherlands	1892-96	23,832,786	6,705	28.1	1910-14	30,394,016	2,115	7.0	21.1	1,283
New Zealand	1892-96	3,382,053	860	25.4	1910-14	5,205,686	362	7.0	18.4	192
Chili	1889-93	13,191,076	3,458	26.2	1910-14	17,526,572	1,198	6.8	19.4	680
Total		885,062,424	702,472	79.4		1,245,803,051	202,581	16.3	63.1	157,143

† Cities only.

CHART I.

Mortality from Diphtheria and Croup



against an average rate of 79.4 during the pre-antitoxin period. This means that within a period of twenty-five years the mortality rate of diphtheria and croup in these combined countries has decreased 63.1 per 100,000 population, or 79.6 per cent. In these twenty countries combined the present annual saving of lives through the use of antitoxin and other improved methods of diphtheria diagnosis and treatment is more than 157,000 per year. On this basis, it is conservatively estimated that not fewer than 250,000 lives are at present (1916) annually saved from the ravages of diphtheria and croup in the various countries of the world where antitoxin is more or less extensively used as a curative agent.

In the United States the positive evidence of the value of antitoxin is so abundant that it is difficult to select the best illustrative examples. Table 2, however, which shows the comparative mortality in twelve representative American cities for pre-antitoxin and antitoxin periods should suffice to convince any skeptics who may yet survive.* In these twelve cities combined the average annual mortality rate of diphtheria and croup has declined from 121.9 per 100,000 of population during 1885 to 1894 to 28.0 during 1905 to 1914—an actual decrease in the death-rate of 93.9, or 76.9 per cent. This means that in these twelve cities only the present annual saving of lives from a terrible form of death is approximately 10,000.

The decline in the mortality from

*See also Chart II, p. 449.

TABLE 2. COMPARISON OF THE MORTALITY FROM DIPHTHERIA AND CROUP IN TWELVE AMERICAN CITIES. PRE-ANTITOXIN AND ANTITOXIN PERIODS.

Cities.	Pre-Antitoxin Period	Antitoxin Period	Reduction in Mortality.	
	1885–1894.	1905–1914.	Antitoxin Period as against Pre-Antitoxin Period.	
	Rate per 100,000 population.	Rate per 100,000 population.	Decrease in the rate.	Average annual reduction in the number of deaths.
Boston	118.1	24.3	93.8	622
Chicago	130.6	33.0	97.6	2,109
Cincinnati	107.4	15.9	91.5	331
Detroit	163.4	31.6	131.8	597
New York (Man. and Bronx)	152.4	33.5	118.9	3,240
Memphis	41.5	15.4	26.1	53
Milwaukee	105.8	26.7	79.1	290
New Orleans	73.2	16.2	57.0	191
Philadelphia	107.4	29.7	77.7	1,193
St. Louis	117.7	21.5	96.2	655
San Francisco	89.5	12.2	77.3	319
Washington	66.0	9.7	56.3	185
Total (12 cities)	121.9	28.0	93.9	9,785

CHART II.

Mortality from Diphtheria and Croup

Fifteen American Cities

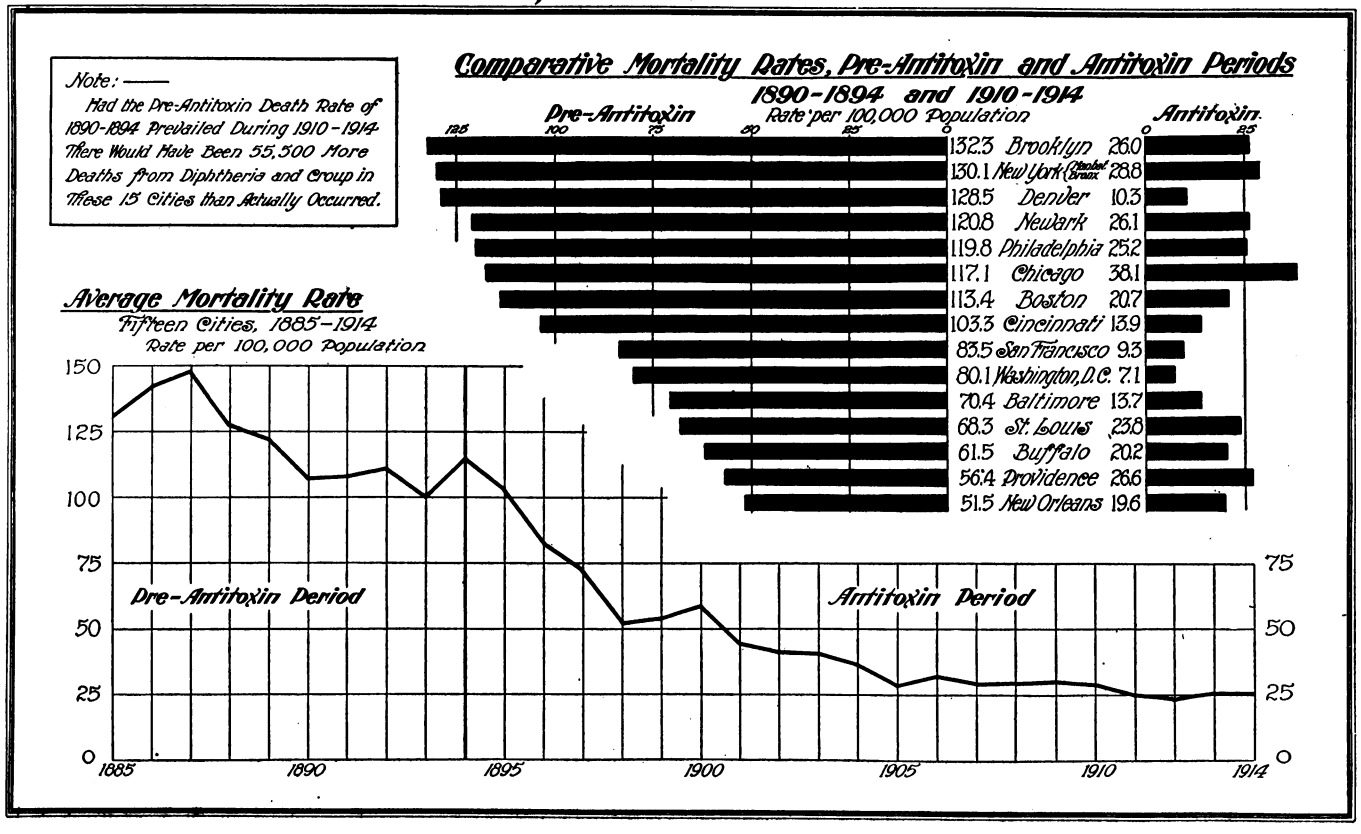


TABLE 3. MORTALITY FROM DIPHTHERIA AND CROUP IN OLD NEW YORK CITY (MANHATTAN AND BRONX BOROUGHS) WITH DISTINCTION OF SEX AND AGE, 1880-1915.

(Rates per 100,000 of Population.)

Under 5 Years of Age.

Years.	Males.			Females.		
	Population.	Deaths.	Rate.	Population.	Deaths.	Rate.
1880-84.....	361,613	4,631	1,280.7	357,550	4,355	1,218.0
1885-94.....	852,785	10,147	1,189.9	846,640	9,227	1,089.8
1895-04.....	1,165,780	5,627	482.7	1,158,380	5,174	446.7
1905-14.....	1,412,620	4,320	305.8	1,389,266	3,604	259.4
1915.....	154,754	305	197.1	151,594	280	184.7

5-14 Years of Age.

Years.	Population.	Deaths.	Rate.	Population.	Deaths.	Rate.
1880-84.....	607,911	1,024	168.4	612,545	1,135	185.3
1885-94.....	1,359,301	2,063	151.8	1,375,052	2,265	164.7
1895-04.....	1,818,820	1,103	60.6	1,836,225	1,290	70.3
1905-14.....	2,297,820	746	32.5	2,324,166	811	34.9
1915.....	254,211	67	26.4	257,653	75	29.1

diphtheria and croup in old New York (Manhattan and Bronx boroughs), with distinction of sex and for the two most important age periods, under 5 years and 5 to 14 years, is illustrated in Table 3.

In Newark, N. J., a very accurate record has been kept of diphtheria cases beginning with 1895 when antitoxin first began to be extensively used in that city.* From the beginning antitoxin has been furnished by the city without charge. In Table 4 there is presented a complete record of this somewhat unique experience of a large American city.

This table shows that there has been a much more favorable mortality in cases where antitoxin has been used than in cases where it was not used. Even in the first five-year period the antitoxin cases had a mortality 50 per cent. less than the others. It is interesting also to note that the fatality per cent. of the antitoxin cases has gradually been reduced from 13.5 in 1895 to only 4.4 in 1915, but no such marked reduction has taken place in the lethal rates of the other cases. These statistics have not been "doctored" by the omission from the antitoxin cases of the so-called "moribund" cases, or cases which terminate

*See Chart I, p. 447.

fatally within twenty-four hours. All cases treated with antitoxin are included under the heading "Antitoxin Used."

Hospital Statistics are even more convincing than general data as to the value of antitoxin as a life saver. The experience of the Boston City Hospital, Table 5, is a typical illustration of reduced fatality among diphtheria cases referred to hospitals for treatment. Many of these were severe cases, and often so far-advanced that tracheotomy or intubation was necessary. All statistics show that operative cases have a higher case fatality than non-operative cases. It is interesting to note that in the ten years previous to antitoxin the fatality per cent. was over 42.0, during 1895 to 1899 it dropped to 12.7, and it is now only 7.6.

TABLE 4. REDUCTION OF DIPHTHERIA MORTALITY IN NEWARK, N. J., AS THE RESULT OF ANTITOXIN, 1895–1915.

	Antitoxin used.			Antitoxin not used.		
Year.	Cases.	Deaths.	Fatality percentage.	Cases.	Deaths.	Fatality percentage.
1895.....	384	52	13.5	937	221	23.6
1896.....	905	106	11.7	356	112	31.5
1897.....	563	61	10.8	406	76	18.7
1898.....	646	68	10.5	373	65	17.4
1899.....	798	70	8.8	372	54	14.5
1895–99.....	3,296	357	10.8	2,444	528	21.6
1900.....	987	80	8.1	430	63	14.7
1901.....	956	58	6.1	198	45	22.7
1902.....	775	61	7.9	210	44	21.0
1903.....	953	71	7.5	197	49	24.9
1904.....	1,399	95	6.8	254	55	21.7
1900–04.....	4,970	365	7.3	1,289	256	19.9
1905.....	1,421	82	5.8	193	28	14.5
1906.....	1,171	72	6.1	102	27	26.5
1907.....	913	64	7.0	126	31	24.6
1908.....	726	49	6.7	80	17	21.3
1909.....	1,117	64	5.7	121	41	33.9
1905–09.....	5,348	331	6.2	622	144	23.2
1910.....	1,252	80	6.4	133	24	18.0
1911.....	1,247	56	4.5	92	18	19.6
1912.....	1,005	76	7.6	93	15	16.1
1913.....	1,489	89	6.0	105	21	20.0
1914.....	1,416	78	5.5	82	11	13.4
1910–14.....	6,409	379	5.9	505	89	17.6
1915.....	1,085	48	4.4	22	4	18.1

TABLE 5. MORTALITY FROM DIPHTHERIA AND CROUP IN THE BOSTON CITY HOSPITAL, 1885–1914.

Years.	Patients under treatment.	Deaths.	Fatality per-centage.
1885–89 ...	1,423	609	42.80
1890–94 ...	2,156	910	42.21
1895–99 ...	7,489	947	12.65
1900–04 ...	8,257	849	10.28
1905–09 ...	6,935	520	7.50
1910–14 ...	6,286	476	7.57

In old New York (Manhattan and Bronx boroughs) the case fatality of diphtheria and croup has decreased from 69.4 per cent. during 1880 to 1884 to 8.2 per cent. during 1915. The details are presented in the following table:

TABLE 6. CASE FATALITY OF DIPHTHERIA AND CROUP IN NEW YORK CITY (MANHATTAN AND BRONX BOROUGHS), 1880–1915.

Years.	Number of cases.	Number of deaths.	Fatality per-centage.
1880–84 ...	16,329	11,332	69.4
1885–94 ...	57,120	24,062	42.1
1895–04 ...	98,753	13,486	13.7
1905–14 ...	90,284	9,232	10.2
1915.....	9,109	750	8.2

The experience of the Metropolitan Asylums Hospitals of London conforms to the data available in this country, as it relates to improvement in the case fatality of diphtheria and croup. In the following table this English experience is summarized by 5-year intervals for the 25-year period, 1890 to 1914. It is interesting to note that if the same average percentage of deaths had obtained during 1910–1914 as in 1890–1894, there would have been 5,568 more deaths during 1910–1914 than actually occurred.

TABLE 7. RESULTS OF DIPHTHERIA CASES WITH REFERENCE TO ANTITOXIN TREATMENT—METROPOLITAN ASYLUMS HOSPITALS, LONDON, ENG., 1890–1914.

Years.	Number of cases.	Number of deaths.	Fatality per-centage.
1890–94 ...	10,777	3,196	29.7
1895–99 ...	29,058	4,928	17.0
1900–04 ...	31,774	3,549	11.2
1905–09 ...	24,733	2,275	9.2
1910–14 ...	25,179	1,910	7.6

There is positive and overwhelming evidence that the earlier the use of antitoxin in any given case the better the result and the greater the chance of recovery. Many statistics could be brought forward to support this conclusion, but Table 8, compiled from the annual reports of the Philadelphia Department of Health, must suffice for this country.

Two periods have purposely been taken, first to show that the same general results appear in both periods and, secondly to show that better results are being secured with continued improvements in the technique of antitoxin use. For the ten-year period, 1905 to 1914, it is shown that the case mortality when antitoxin was administered the first day of the onset of the disease was only 0.7 against 5.3 for the second day, 7.7 for the third,

TABLE 8. SUMMARY OF MORTALITY FROM DIPHTHERIA IN PHILADELPHIA, PA., BY DURATION OF THE DISEASE AT TIME OF ANTITOXIN TREATMENT.*

	1905–1909.			1910–1914.			1905–1914.
	Number of cases.	Number of deaths.	Fatality percentage.	Number of cases.	Number of deaths.	Fatality percentage.	Fatality percentage.
First day ...	415	...	....	443	5	1.1	0.7
Second day .	2,125	107	5.0	2,285	128	5.6	5.3
Third day ..	1,661	146	8.8	2,197	150	6.8	7.7
Fourth day..	999	124	12.4	1,409	108	7.7	9.6
Fifth day...	543	79	14.5	673	62	9.2	11.6
Sixth day...	381	52	13.6	462	43	9.3	11.3
After sixth day.....	637	91	14.3	595	68	11.4	12.9
Total	6,761	599	8.9	8,064	564	7.0	7.8

* These statistics are exclusive of diphtheria cases complicated with other infectious diseases. They are also exclusive of cases dying within 24 hours of treatment.

9.6 for the fourth, over 11 per cent. for the fifth and sixth days and 12.9 per cent. for such cases as were not treated with antitoxin until after at least six days duration of the disease. These statistics are strikingly significant of the importance of the early use of antitoxin and they also substantiate the now almost universally accepted claim that antitoxin is one of the main factors which have contributed to the decline in diphtheria mortality since 1894.†

The following quotation bears directly upon this point and is well worth a very careful reading by every physician and health official: "The death-rate among actual cases has been immensely lowered by the use of antitoxin. It is the duty of the State to place an adequate supply at the disposal of every practicing physician, to do everything possible to encourage its use and to provide for its administration to those who are unable to pay for the services of a private physician. This is all that can reasonably be expected from health officials. The further lowering of the death-rate rests absolutely in the hands of practicing physicians."‡

Discussing a paper on Diphtheria in Elementary Schools and Its Prevention, by J. Wright Mason, Medical Officer of Health, Kingston-upon-Hull, Dr. J. M. Clements of Hull, Eng., made the following statement: "The mortality among cases coming under my care from 1903 to 1906, classified according to the day of the disease on which serum treatment commenced, showed that of those coming under treatment on the first day the mortality was *nil;* second, 1.5 per cent.;

† See Chart I, p. 447.

‡ A Plea for the Early Use of Antitoxin in Diphtheria. Matthias Nicoll, Jr., M. D., *Health News*, November, 1915, N. Y. State Department of Health.

third, 8.0 per cent.; fourth, 15.7 per cent.; fifth, 19.8 per cent.; sixth, 24.0 per cent. These figures tallied very closely with the much larger figures collected by Doctor McCombie, of the Brook Hospital. They showed the great importance of giving serum early in the disease, and the large number of lives that would be saved if all cases came under antitoxin on the first or second day of illness." *

The State Department of Health of Pennsylvania for a number of years has made a systematic effort to extend the use of antitoxin, has furnished the serum free for dispensary use, and has kept a statistical record of the results achieved. The following tables should, therefore, be of general interest:

TABLE 9. RESULTS OF ANTITOXIN CURATIVE TREATMENT OF DIPHTHERIA, STATE OF PENNSYLVANIA, NOVEMBER 4, 1905 TO DECEMBER 31, 1912.†

Years.	Number treated.	Deaths.	Fatality percentage.
1905.....	293	38	12.97
1906.....	3,529	393	11.14
1907.....	5,271	376	7.13
1908.....	6,336	542	8.55
1909.....	5,365	416	7.75
1910.....	6,524	559	8.57
1911.....	7,793	510	6.54
1912.....	9,919	763	7.69
Total ...	45,030	3,597	7.99

† The total number of recoveries during the period, 1905-1912, was 41,433, or 92.01 per cent. of the cases treated.

Since 1906 the case fatality rates of antitoxin-treated cases have remained about the same from year to year and the rates indicate that there is too much delay in the use of the serum.

In the next table the results in Pennsylvania of antitoxin treatment for immunization purposes are presented for an eight-year period:

TABLE 10. RESULTS OF ANTITOXIN TREATMENT FOR IMMUNIZATION PURPOSES, STATE OF PENNSYLVANIA, NOVEMBER 4, 1905 TO DECEMBER 31, 1912.‡

Years.	Number treated.	Number developing diphtheria.	Deaths.	Fatality percentage in diphtheria cases.
1905....	155	5	..	....
1906....	2,384	77	3	3.90
1907....	3,799	34	2	5.88
1908....	3,965	45	8	17.78
1909....	4,847	109	3	2.75
1910....	5,194	87	6	6.90
1911....	6,906	125	4	3.20
1912....	8,581	94	3	3.19
Total	35,781	576	29	5.03

‡ Source: Report of Commissioner of Health, State of Pennsylvania, 1912, Part 2, p. 865.

The use of antitoxin to temporarily immunize susceptible individuals in diphtheria epidemics or in scarlet fever patients segregated in hospitals is likely to play a very important rôle in the future. As Dr. William H. Park and others have pointed out this is now made feasible by the perfection of the technique of the Schick test. There is already sufficient evidence to indicate that along this line of effort lies the hope that antitoxin may prove quite as important in preventing diphtheria as in curing it. To date there is no conclusive evidence that diph-

* Transactions of the Sanitary Institute, June, 1908, pp. 227-8.

theria morbidity has decreased, but there can be no reasonable doubt that its mortality has declined and mainly as the direct result of antitoxin treatment.

Notwithstanding the great reduction in the diphtheria death-rate as a direct result of antitoxin, better diagnosis, more general hospital care, etc., diphtheria is still responsible for at least three per cent. of the total mortality at ages under 15 years in the countries of the temperate zones for which reliable vital statistics are available. In the registration area of the United States this percentage is 4.4; in England and Wales it is 2.9; in Norway, 6.0; in Austria, 4.5; and in Bavaria, 3.1.

Diphtheria still causes more deaths in the United States than whooping-cough, measles or scarlet fever. This disease, therefore, still remains a distinct menace to children notwithstanding antitoxin, its specific curative agent. The average annual number of deaths from diphtheria and croup in the United States is approximately 17,000, against 10,000 from whooping-cough, 9,000 from measles and 8,000 from scarlet fever. In Table 11 the relative importance of these four diseases is clearly set forth and with distinction of age.

It is interesting to note that diphtheria and croup causes a larger percentage (3.3) of the total mortality at ages under five years than any of the

TABLE 11. COMPARATIVE MORTALITY FROM DIPHTHERIA AND CROUP, WHOOPING-COUGH, MEASLES, AND SCARLET FEVER. REGISTRATION AREA, U. S., 1910–1914.

Age.	Diphtheria and Croup.			Whooping-cough.		
	Deaths.	Percentage distribution by age.	Percentage of total deaths, all causes.	Deaths.	Percentage distribution by age.	Percentage of total deaths, all causes.
Under 5 years ...	35,691	62.2	3.3	30,074	95.2	2.8
5–9 years.....	14,871	25.9	16.0	1,167	3.7	1.3
10–19 years	4,497	7.8	2.8	175	0.5	0.11
20 and over	2,355	4.1	0.08	179	0.56	0.01
All ages.....	57,414	100.0	1.34	31,595	100.0	0.74
	Measles.			Scarlet Fever.		
Under 5 years ...	23,649	80.6	2.2	13,685	53.9	1.3
5–9 years.....	2,446	8.3	2.6	7,176	28.3	7.7
10–19 years	1,233	4.2	0.8	2,881	11.4	1.8
20 and over	2,001	6.8	0.07	1,632	6.4	0.05
All ages.....	29,329	100.0	0.68	25,374	100.0	0.59

other three diseases, whooping-cough being second with 2.8 per cent., measles third with 2.2 per cent. and scarlet fever fourth with 1.3 per cent. At ages 5 to 9 years diphtheria and croup causes no less than 16.0 per cent. of the total mortality from all causes at those ages, scarlet fever is second with 7.7 per cent.; measles is third with 2.6 per cent. and whooping-cough is fourth with only 1.3 per cent. At ages 15 to 19 years diphtheria and croup causes 2.8 per cent. of the total mortality, scarlet fever 1.8 per cent., measles 0.8 per cent. and whooping-cough only 0.11 per cent. At the adult ages, 20 years and over, no one of these four diseases causes as much as one-tenth of one per cent. of the total mortality.*

This comparison is interesting also from the viewpoint of age distribution of the deaths. Diphtheria and croup, in this respect, resembles scarlet fever more closely than measles or whooping-cough. A greater proportion of the whooping-cough deaths occur at ages under five years (95.2 per cent.) than is true of any of the other three causes. Measles is second with 80.6 per cent., diphtheria is third with 62.2 per cent. and scarlet fever is fourth with 53.9 per cent. At the other age extreme, 20 years and over, measles stands first with 6.8 per cent. of its deaths occurring at those ages, scarlet fever is a close second with 6.4 per cent., diphtheria is third with 4.1 per cent. and whooping-cough is a poor fourth with only 0.56 per cent. of its total mortality falling within the age period 20 years and over.

* See Chart V, p. 470.

Geographical Distribution.

Diphtheria, so far as can be determined from official reports, is world-wide in its distribution. The average annual death-rates from this disease differ widely in the various countries in any given period of time. Just what the underlying factors are which contribute to this result and what their relative importance is still a more or less baffling mystery. Temperature is probably the climatic factor of most importance in determining the extent of the spread of diphtheria and its seasonal prevalence. Clemow concludes "That temperature is a powerful factor in determining the distribution of this disease, and that extremes of heat or cold are unfavorable to its prevalence." He concludes that "Heat is probably more unfavorable than cold, for while diphtheria is found as a severe epidemic in no tropical country, it is endemic and a cause of high mortality in such cold countries as Norway and Sweden. Clemow was well aware also that "Diphtheria in many temperate countries is found to be most active in the autumn and winter, and least so in the warm summer months." †

Many writers, including Longstaff, Newsholme, Creighton, and Marsden, have sought to establish a correlation between diphtheria epidemics and a succession of dry years; in other words, an inverse or negative correlation between diphtheria mortality and a high level of ground water. In England and Wales this negative correlation is high, or more than −0.6. In

† Clemow, The Geography of Disease, p. 145.

Norway, however, the factor of inverse correlation is insignificant and the same is true of Newark, N. J., although long periods of years have been taken in both these latter cases. Rainfall may be a conditioning factor in diphtheria prevalence, but it evidently is only one of many, for there are numerous and important exceptions to its dominating influence.* Altitude and soil have been considered by some authorities to have an important effect on the diffusion of diphtheria but nothing like definite proof is yet possible from the available statistics of this disease.

The seasonal prevalence of diphtheria in most temperate climates is probably associated with bad ventilation and closer contact of larger numbers of susceptible persons in schools, houses, etc., in the winter than in the summer season. Whatever the cause, it is almost universally true that diphtheria cases in Northern latitudes reach a minimum in August or September, then gradually increase throughout the late fall and winter, attaining a maximum or high crest in April or May. Some writers attribute a large part of this school-season diphtheria to compulsory school attendance but Newsholme, Chapin and others have repeatedly pointed out that the great majority of the cases of diphtheria are of children under school age. The seasonal prevalence of diphtheria and croup in Greater New York is illustrated in the accompanying Chart III, page 458. The weekly rates of cases and deaths in New York City are typical of those for any large American city.

Just as the seasonal distribution of diphtheria may possibly be correlated with closer and more confined grouping of the population in schools, houses, shops, etc., so the more general close-crowding of population in cities as compared with rural areas seems to afford a ready explanation for some of the comparative differences in the death-rates from diphtheria.

In the United States the diphtheria mortality is at present considerably higher in the urban than in the rural areas,† as is clearly shown in Table 12.

In every one of the fifteen years, 1900 to 1914, the urban death-rate has been materially higher than the rural rate. It is significant also to note that comparing the death-rates for the first and last five-year periods the average annual death-rate in the urban area has declined from 42.8 per 100,000 population during 1900 to 1904 to 21.7 during 1910 to 1914, or nearly 50.0 per cent., while the decline in the rural rate has been from 20.1 to 15.0, or only 25.0 per cent. The urban death-rate is being so well controlled by antitoxin treatment that it is probable that it will soon be no more than equal to or even lower than the rural death-rate.

The geographical distribution of diphtheria mortality in the United States during the fifteen-year period, 1900 to 1914, is succinctly set forth in Tables 13 and 14, pp. 460 and 461.

These tables show a progressive increase in the rate from the west east-

* In testing out these correlations, I have had the assistance of Mr. Arne Fisher, one of my co-workers, and author of the well-known work on the Mathematical Theory of Probabilities.

† See Chart I, p. 447.

CHART III.

Seasonal Prevalence of Diphtheria and Croup
New York City, 1911 to 1915

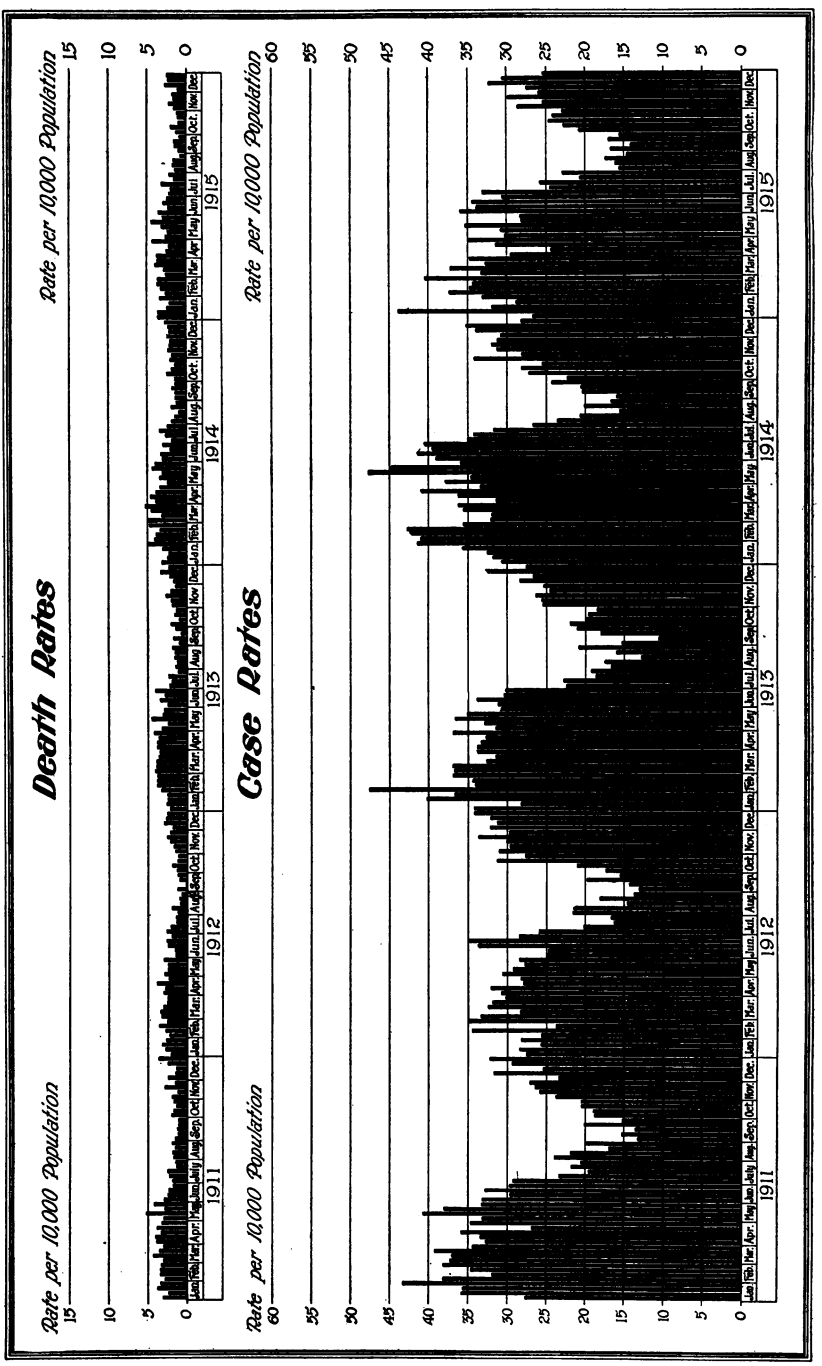


TABLE 12. MORTALITY FROM DIPHTHERIA AND CROUP IN THE REGISTRATION AREA OF THE UNITED STATES WITH DISTINCTION OF URBAN AND RURAL AREAS, 1910–1914.

	Urban.*			Rural.		
	Population.	Deaths.	Rate per 100,000.	Population.	Deaths.	Rate per 100,000.
1900	10,675,611	5,591	52.4	9,289,538	2,465	26.5
1901	11,188,101	4,816	43.0	9,118,942	1,966	21.6
1902	11,477,929	4,568	39.8	9,171,012	1,560	17.0
1903	11,754,911	4,878	41.5	9,235,930	1,638	17.7
1904	12,029,302	4,623	38.4	9,307,413	1,634	17.6
1900–04	57,125,854	24,476	42.8	46,122,835	9,263	20.1
1905	12,372,228	3,712	30.0	9,364,680	1,408	15.0
1906	18,195,041	5,815	32.0	15,640,988	3,076	19.7
1907	18,737,525	5,493	29.3	15,871,371	2,873	18.0
1908	20,417,270	5,455	26.7	18,288,591	3,021	16.5
1909	23,066,405	5,632	24.4	21,215,280	3,182	15.0
1905–09	92,788,469	26,107	28.1	80,380,910	13,560	16.9
1910	25,187,805	6,482	25.7	22,619,961	3,608	16.0
1911	27,485,457	5,883	21.4	26,899,777	4,075	15.1
1912	28,129,824	5,502	19.6	27,122,299	4,207	15.5
1913	29,244,160	6,324	21.6	29,068,435	4,280	14.7
1914	30,287,640	6,320	20.9	30,826,560	4,243	13.8
1910–14	140,334,886	30,511	21.7	136,537,032	20,413	15.0

* By urban is meant all municipalities of 10,000 or more population.

ward and from the south northward, density of population, with all that it implies, apparently playing an important rôle in the geographical distribution of diphtheria mortality. In the southern states, however, the mild climate and more general out-of-doors life and the large negro population are factors which doubtless operate to keep the diphtheria death-rate lower than in the north, entirely aside from the question of relative population density. On the Pacific coast also the generally mild climate with rainy season intervals may account in part, at least, for the comparatively low diphtheria death-rate.

Epidemicity.

Newsholme has probably written the best and most comprehensive work on the epidemicity of diphtheria.† He brings forward abundant evidence to support the theory that this disease is epidemic in character and has now become endemic and pandemic in most, if not all, the temperate countries of the world. The statistics of the United States which were drawn upon

† Epidemic Diphtheria, by Arthur Newsholme, M. D., London, 1898.

TABLE 13. MORTALITY FROM DIPHTHERIA AND CROUP IN THE UNITED STATES, REGISTRATION STATES, POPULATION AND DEATHS, AGES UNDER 20, 1910–1914.

	Population.	Deaths.	Rate per 100,000 population.
9 Eastern States:			
Maine	1,363,083	425	31.2
New Hampshire	760,720	320	42.1
Vermont	652,853	137	21.0
Massachusetts	6,258,765	2,945	47.1
Rhode Island	1,057,367	647	61.2
Connecticut	2,141,857	1,138	53.1
New York	17,399,602	9,602	55.2
New Jersey	5,159,810	2,915	56.5
Pennsylvania	16,059,381	10,061	62.6
Total	50,853,438	28,190	55.4
4 Southern States:			
Maryland	2,691,459	887	33.0
Virginia (1913 and 1914)	2,032,531	625	30.7
North Carolina	886,114	287	32.4
Kentucky (1911 and 1914)	4,332,033	2,355	54.4
Total	9,942,137	4,154	41.8
7 Central States:			
Ohio	9,218,466	4,028	43.7
Indiana	5,360,838	2,111	39.4
Michigan	5,668,623	2,443	43.1
Minnesota	4,524,888	1,437	31.8
Wisconsin	5,094,066	1,453	28.5
Missouri (1911–1914)	5,500,431	2,489	45.3
Kansas (1914)	747,872	159	21.3
Total	36,115,184	14,120	39.1
3 Rocky Mountain States:			
Colorado	1,602,620	393	24.5
Montana	712,062	145	20.4
Utah	930,115	245	26.3
Total	3,244,797	783	24.1
2 Pacific Coast States:			
California	3,994,562	920	23.0
Washington	2,249,047	375	16.7
Total	6,243,609	1,295	20.7
Grand total (25 Registration States)	106,399,165	48,542	45.6

TABLE 14. GEOGRAPHICAL DISTRIBUTION OF THE MORTALITY FROM DIPHTHERIA AND CROUP IN ONE HUNDRED CITIES OF THE UNITED STATES, 1900–1914.

Geographical areas.	Number of cities.	Aggregate population.	Number of deaths from diphtheria and croup.	Death-rate per 100,000 total population.
Middle Atlantic	29	136,554,575	49,442	36.2
New England	20	35,305,335	10,496	29.7
East Central	16	66,638,804	19,077	28.6
West Central	9	30,294,114	7,921	26.1
Rocky Mountain	3	4,689,215	1,170	25.0
Southern	16	35,383,983	6,064	17.1
Pacific Coast	7	15,989,672	2,575	16.1

extensively by Newsholme in 1898 are even more conclusively confirmatory today of his main thesis that diphtheria, although endemic and pandemic is still epidemic both in a local and in a universal sense. There is evidence that diphtheria epidemics spread in great waves and that possibly they are favored by certain climatic and meteorological conditions, even though personal infection is the most important single factor in the spread of diphtheria infection. Anything like an exhaustive statistical reëxamination of the epidemic character of diphtheria is beyond the scope of this paper, and is quite unnecessary in view of Newsholme's work. In this connection, however, it is interesting to note that in each of 100 cities of the United States during a period of fifteen years,

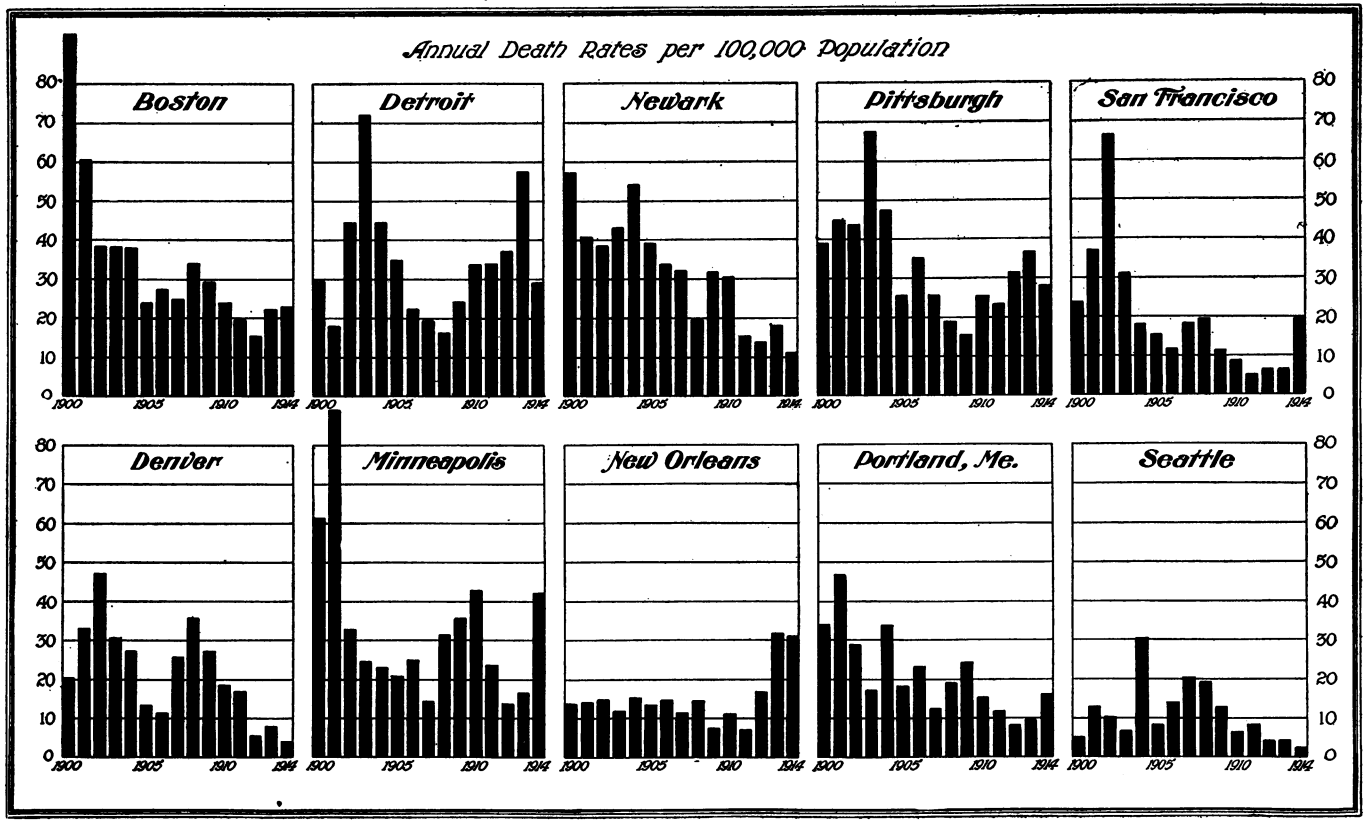
TABLE 15. MORTALITY FROM DIPHTHERIA, TWENTY REPRESENTATIVE AMERICAN CITIES, 1900–1914.

(Death-rates per 100,000 Population, All Ages.)

Cities.	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914
Baltimore	57.4	33.2	24.3	29.4	21.2	17.6	20.8	14.7	12.0	13.7	11.4	12.0	15.8	15.0	14.8
Boston	92.4	60.2	38.3	38.2	37.9	23.9	27.4	24.8	33.9	29.5	23.9	19.7	15.3	22.1	22.9
Charleston, S. C.	19.7	17.8	14.2	3.5	8.8	5.2	5.2	12.1	1.7	8.5	13.6	8.4	6.7	5.0	6.7
Chicago	49.6	28.6	34.7	34.2	21.4	22.3	27.5	27.1	26.5	31.7	37.4	38.2	41.2	41.2	32.2
Cincinnati	27.9	21.6	23.2	18.4	13.3	22.6	22.5	14.9	15.9	11.4	9.9	12.2	15.7	13.1	18.2
Denver	20.2	33.1	47.0	30.4	27.3	13.4	11.3	25.9	35.4	27.0	18.6	16.7	5.6	8.0	4.1
Detroit	29.1	18.0	44.4	71.7	44.4	34.7	22.6	19.6	16.1	24.3	33.8	33.9	37.1	57.6	29.2
Fall River	23.8	23.8	47.5	40.8	27.5	26.5	25.7	20.6	19.2	17.1	19.2	22.0	26.1	27.4	20.7
Minneapolis	61.2	89.0	32.7	24.8	23.2	21.0	25.1	14.3	31.4	35.6	42.9	23.8	13.9	16.8	42.2
Newark	57.3	40.8	38.8	43.1	54.2	39.2	33.9	32.2	19.5	31.7	30.6	15.7	14.1	18.2	11.1
New Orleans	13.9	14.3	14.8	11.9	15.2	13.4	14.7	11.4	14.6	7.5	10.9	7.2	16.5	31.7	31.0
New York (Greater)	65.7	56.2	54.7	55.1	52.7	37.3	44.4	39.3	38.1	36.7	35.6	25.6	22.3	26.1	28.3
Philadelphia	85.1	49.2	38.4	44.9	39.1	32.7	39.0	33.5	32.5	33.4	30.8	31.1	23.7	21.5	19.4
Pittsburg	39.0	44.8	43.5	67.3	47.7	25.6	35.1	25.3	18.8	15.5	25.4	23.4	31.2	36.6	28.0
Portland, Me.	33.9	47.0	28.9	17.1	33.6	18.4	23.5	12.5	19.3	24.2	15.3	11.7	8.3	9.8	16.1
Providence	31.3	47.7	39.0	44.3	45.9	36.2	25.0	32.0	36.8	26.3	21.7	24.7	32.7	29.6	24.1
St. Louis	66.8	47.3	29.6	32.3	27.4	25.6	17.7	17.4	19.0	26.0	16.1	17.6	21.2	29.2	34.7
San Francisco	23.9	37.0	66.4	31.2	18.2	15.5	11.8	18.4	19.6	11.2	8.8	5.2	6.7	6.6	19.4
Seattle	5.0	12.8	10.4	6.8	30.1	8.5	14.2	20.2	19.5	13.0	6.3	8.7	4.3	4.4	2.2
Washington, D. C.	43.4	36.6	17.3	8.5	17.3	16.0	13.5	9.2	8.4	14.4	9.3	5.6	4.4	7.8	8.2

CHART IV.

Mortality from Diphtheria and Croup



1900 to 1914, there was one or more deaths from diphtheria every year, with only one exception. During this period of fifteen years the annual diphtheria death-rates of the 100 cities (1500 rates) varied from zero, in the one exceptional case, to 173 per 100,000 of population. Practically every one of the cities also presented evidence of the epidemic character of diphtheria in the varying annual death-rates during the fifteen-year period. These facts are illustrated for ten representative cities in Chart IV, page 462. The detail statistics upon which that chart is based are presented in Table 15, p. 461, which includes the data for twenty of the one hundred cities previously referred to and embraces the ten cities represented in Chart IV.

Race.

Hirsch directed attention to the probability that there is no complete racial immunity to diphtheria.* He stated, however, that "in several of the epidemics in the United States, the negro children, who live under the most unfavorable conditions, have enjoyed a striking immunity from the disease."† Hoffman in his "Race Traits and Tendencies of the American Negro" called attention to the probably lesser liability of the colored race (negroes) to diphtheria and croup as compared with the white population.‡ Clemow remarks that "all the great divisions of the human family, including pure Mongols and full-blooded negroes, seem to be capable of becoming subjects of the disease, though probably both their susceptibility to attack and their power of recovery when attacked vary greatly. In China, for example, the disease is said to be much more intense and fatal in natives than in European residents, while in the United States the white races suffer much more than the black."§

In a very recent analysis of 3,778 deaths from scarlet fever in the Metropolitan Life Insurance Company's experience, Dublin has pointed out that the mortality was "markedly lower" for the colored than for the whites,|| and as scarlet fever follows closely in many respects the sex, age, and race characteristics of diphtheria it is safe to assume that the Metropolitan's experience with diphtheria will confirm that available in the general mortality of American cities and states.¶

In thirty southern cities combined, during the five years, 1909–1913, the average annual death-rate of the white population from diphtheria and croup was 13.7 per 100,000 of population, against an average rate of only 8.1 for the negro population. In Washington, D. C., the comparative data have been recorded for a number of years and include reported cases of diphtheria and croup as well as deaths. As Table 16 shows, the attack rates, as well as the death-rates, have been considerably higher for the white than

* Handbook of Geographical and Historical Pathology, by Dr. August Hirsch, Vol. III, p. 106, London, 1886.

† *Ibid.*, p. 110.

‡ Race Traits and Tendencies of the American Negro, by Frederick L. Hoffman, pp. 113–115. The MacMillan Co., N. Y., 1896.

§ The Geography of Disease, by Frank G. Clemow, M. D., D. P. H., p. 146. Cambridge, Eng., 1903.

|| A Study of 1,153 Cases of Scarlet Fever, by Louis I. Dublin, Ph. D., 1916.

¶ See Chart I.

TABLE 16. ATTACK- AND DEATH-RATES FROM DIPHTHERIA AND CROUP IN WASHINGTON, D. C., BY AGE AND RACE, 1908–1915.

(Rates per 10,000 Population.)

Age.	Population.	Cases.	Attack-rate.	Deaths.	Death-rate.
White.					
Under 1 year	33,122	66	19.9	8	2.42
1–4 years	126,643	700	55.3	86	6.79
5–9 years	150,024	1,118	74.5	51	3.40
10–19 years	303,947	788	25.9	10	0.33
20 and over	1,328,794	551	4.1	9	0.07
All ages	1,942,530	3,223	16.6	164	0.84
Colored.					
Under 1 year	11,591	13	11.2	4	3.45
1–4 years	47,906	87	18.2	21	4.38
5–9 years	58,724	144	24.5	11	1.87
10–19 years	129,815	347	26.7	5	0.39
20 and over	520,804	144	2.8	5	0.10
All ages	768,840	735	9.6	46	0.60

for the colored population, except at ages 10 to 19 years when the rates have been about the same for white and colored. The attack rate for all ages combined, during the eight-year period, 1908 to 1915, was 16.6 per 10,000 white population as against only 9.6 for the colored. The comparative death-rates were 0.84 per 10,000 white population as against 0.60 for the colored.

The comparative mortality from diphtheria and croup of the white and colored races of Cuba are presented in Table 17 for the period 1910 to 1913, and according to age. These Cuban data show a white death-rate, ages 1 to 9 years, more than double the negro rate. The deaths for the other age periods are too few to give trustworthy rates.

The case-fatality is possibly markedly higher among negroes than among whites. At least that is the deduction to be made from the following statistics in Table 18, compiled from the excellent reports of the Health Department of Washington, D. C.

It is quite possible that some of these differences in the comparative case fatality may be the result of less complete reporting of negro cases of diphtheria. Probably, however, they are more readily to be explained as the result of less prompt and adequate treatment of the negro cases, with antitoxin and otherwise.

Only fragmentary data are available

TABLE 17. MORTALITY FROM DIPHTHERIA AND CROUP, BY AGE AND RACE, IN CUBA, 1910–1913.*

Ages.	White.			Colored.		
	Population.	Deaths.	Rate per 100,000 population.	Population.	Deaths.	Rate per 100,000 population.
Under 1 year....	211,666	47	22.2	78,162	19	24.3
1–9 years.....	1,582,867	501	31.7	673,895	99	14.7
10–19 years	1,290,978	20	1.5	579,488	7	1.2
20 years and over	3,315,086	7	0.2	1,450,925	6	0.4
All ages.....	6,400,597	575	9.0	2,782,470	131	4.7

* Source: Sanidad y Benificencia, Boletin Oficial de la Secretaria, Habana.

TABLE 18. DIPHTHERIA AND CROUP, WHITE AND COLORED, WASHINGTON, D. C.

Years.	White.			Colored.		
	Cases.	Deaths.	Case fatality percentage.	Cases.	Deaths.	Case fatality percentage.
1896–1905.....	4,913	625	15.0	1,299	306	23.6
1906–1915.....	3,969	212	5.7	820	62	7.6
Total.....	8,882	837	9.4	2,119	368	17.4

to show the relative susceptibility of the American Indian to diphtheria and croup but so far as they go they indicate a lesser degree of susceptibility than for the Caucasian race. Chinese and Japanese, Hawaiians, Filipinos and Mexicans all are susceptible to diphtheria, and apparently equally so with Caucasians.

According to a special tabulation of the U. S. Bureau of the Census for the year 1910, out of a total of 886 deaths of Indians from all causes, only 3 were from diphtheria and croup; out of a total of 1,055 deaths of Chinese for the same year and same area (U. S. Registration area) there were 8 deaths from diphtheria and croup and out of 664 deaths of Japanese from all causes during the same year and for the same area, there were 3 deaths from diphtheria and croup. The child population, however, is a much more important element in the Indian than in either the Chinese or Japanese populations of the United States.

During this same year and for the same area there were reported 25 deaths of Indians from measles, 3 deaths from scarlet fever and 25 deaths from whooping-cough; among the Chinese there were reported 2 deaths from measles, no death from scarlet fever and 1 death from whooping-cough; among the Japanese there were reported 1 death from measles, no death from scarlet fever, and 10 deaths from whooping-cough. It is the opinion of Indian agency physicians that diphtheria is infrequently met with among Indians, and it is very infrequently noted on the agency morbidity reports.* During the six-year period, 1888 to 1893, only 325 cases of diphtheria were reported by Indian agency physicians of the United States as against 4,003 cases of whooping-cough and 7,805 cases of measles in the same Indian population.†

The mortality of Chinese from diphtheria in San Francisco, 1910–1914, according to a special investigation into the mortality of the Chinese in that city during the five-year period, 1910–1914, was as follows: 4 deaths from diphtheria, of which 3 occurred at ages under 15, and 1 in the age group 15–39. There were no deaths from diphtheria reported among the female Chinese population, but that population, is of course, quite limited in number.

According to a special investigation into the mortality of Mexicans in the cities of San Diego, Los Angeles, El Paso and San Antonio during the five-year period, 1910–1914, the mortality from diphtheria among Mexicans in these cities was as follows: *Males*, ages under 15 years, 38 deaths; 15–44 years, no deaths; 45 and over, no deaths; total, 38 deaths, or 0.6 per cent. of the deaths from all causes among male Mexicans. *Females*, ages under 15 years, 36 deaths; 15 to 44 years, 5 deaths; 45 and over, no deaths; total, 41 deaths, or 0.8 per cent. of the reported deaths of female Mexicans from all causes.

Because of their general interest and as bearing directly upon the question of relative racial susceptibility Tables 19 and 20 for the city of Manila and for the Hawaiian Islands are included.

Sex.

Thorne stated in 1894 that "Sex appears to have some slight influence in determining a liability to the disease (diphtheria) though it is not well marked. We find that more females die from the disease than males, but I have thought that this arises mainly from the fact that females are more exposed to infection than males. Little girls, when they are sick, are not nursed by little boys, but little boys are often nursed by little girls, and this care for the sick by females holds good in adult life. Men do not usually nurse women suffering from diphtheria, whereas males thus affected are usually nursed by women. A fallacy therefore underlies the figures bearing on the incidence of the disease as it affects the sexes, in so far as the mere influence of sex is concerned."‡

* Contagious and Infectious Diseases Among the Indians. Senate Document, No. 1038, pp. 57 and 58. Washington, D. C., 1913.

† Statistics compiled from the annual reports of the U. S. Commissioner of Indian Affairs.

‡ The Etiology, Spread and Prevention of Diphtheria, by R. Thorne Thorne, Sanitary Institute, April, 1894.

TABLE 19. MORTALITY FROM DIPHTHERIA AND CROUP IN THE CITY OF MANILA, P. I., BY RACES, 1905–1914.

Race.	Total population.	Population under 20.	Deaths.	Rate per 100,000	
				Total population.	Population. under 20.
American	47,585	5,948	3	6.3	50.4
Chinese	176,065	10,388	..	..	..
Filipino	2,108,016	834,775	77	3.7	9.2
All others	47,586	25,506	1	2.1	3.9
Total	2,379,253	876,617	81	3.4	9.2

TABLE 20. MORTALITY FROM DIPHTHERIA AND CROUP IN HAWAII, BY RACES, JULY 1, 1911 TO JUNE 30, 1915.

Race.	Total population.	Population under 20.	Deaths.	Rate per 100,000	
				Total population.	Population under 20.
Hawaiian	99,423	39,670	10	10.1	25.2
Part-Hawaiian	55,804	36,831	6	10.8	16.3
Chinese	83,723	24,196	9	10.7	37.2
Japanese	344,435	97,475	43	12.5	44.1
Portuguese	94,093	53,445	14	14.9	26.2
Other Caucasian	123,820	44,947	15	12.1	33.4
All others	68,833	20,306	3	4.4	14.8
Total	870,131	316,870	100	11.5	31.6

Longstaff states that he found the total female mortality from diphtheria to be seven per cent. in excess of the male mortality in England after population differences were allowed for. His statistics also showed that this excessive female mortality occurred mainly between the fifth and fifteenth years of age.*

Creighton states that "Diphtheria is the only epidemic disease besides whooping-cough which is more fatal to females than to males in proportion to the numbers of each sex living."†

For England and Wales during the five-year period, 1909 to 1913, the comparative death-rates of males and females are shown in detail, and with distinction of age, in Table 21. The percentage distribution, by age, of the deaths from diphtheria and croup dur-

* Studies in Statistics, Longstaff, p. 336.

† History of Epidemic Diseases of Britain, Vol. II, p. 743.

ing this five-year period is also shown for each sex.

In view of the various observations of English writers, previously quoted, it is interesting to note that, according to this table, the general mortality rate has been practically the same for both sexes, but slightly higher for males than for females or as 13.2 to 13.0 per 100,000 of population. When the death-rates are studied by age, however, the female death-rate is seen to be distinctly higher than the male rate at ages 5–9 years, 10–14 years and 20 years and upward. At age 4 years also the female rate was slightly higher than the male rate, but at ages under 4 years and at ages 15 to 19 years the male death-rates were distinctly higher than the female rates for the corresponding ages.

The data for the registration area of the United States, for the five-year period, 1910 to 1914, exhibit much the same sex differences as the English

TABLE 21. MORTALITY FROM DIPHTHERIA AND CROUP, ENGLAND AND WALES, 1909–1913

Age at death.	Population.	Deaths.	Rate per 100,000.	Percentage distribution of deaths by age.	
Under 1 year	1,981,051	632	31.9	5.5	
1 year	1,875,220	1,417	75.6	12.3	
2 years	1,985,424	1,474	74.2	12.8	
3 years	1,948,689	1,679	86.2	14.6	
4 years	1,916,328	1,582	82.6	13.8	
Under 5 years	9,706,712	6,784	69.9	59.0	
5–9 years	9,261,522	3,736	40.3	32.5	
10–14 years	8,762,105	621	7.1	5.4	
15–19 years	8,296,798	134	1.6	1.2	
20 years and over	51,436,477	230	0.4	1.9	
All ages	87,463,614	11,505	13.2	100.0	
Females.					Ratio of female deaths to every 100 males.
Under 1 year	1,938,462	468	24.1	3.9	76
1 year	1,848,822	1,259	68.1	10.4	90
2 years	1,972,080	1,328	67.3	10.9	91
3 years	1,948,734	1,607	82.5	13.2	96
4 years	1,909,517	1,627	85.2	13.4	103
Under 5 years	9,617,615	6,289	65.4	51.8	94
5–9 years	9,272,128	4,740	51.1	39.0	127
10–14 years	8,783,777	705	8.0	5.8	113
15–19 years	8,430,820	122	1.4	1.0	88
20 years and over	57,270,561	296	0.5	2.4	125
All ages	93,374,901	12,152	13.0	100.0	98

data, as is evident from the following table:

TABLE 22. MORTALITY FROM DIPHTHERIA AND CROUP IN THE REGISTRATION AREA, U. S., BY SEX AND AGE, 1910–1914.

(Rates per 100,000 Population at Specified Ages.)

Males.

Age.	Population.	Deaths.	Rate.
Under 1 year...	3,337,487	2,523	75.6
1 year.....	2,974,647	5,062	170.2
2 years.....	3,262,362	4,555	139.6
3 years.....	3,224,000	4,004	124.2
4 years.....	3,185,638	3,059	96.0
Under 5 years..	15,984,134	19,203	120.1
5–9 years.....	14,377,589	7,278	50.6
10–14 years....	13,793,089	1,598	11.6
15–19 years....	14,314,597	532	3.7
20 years and over.....	97,320,276	1,055	1.1
Ages unknown	.....	7	....
All ages	155,789,685	29,673	19.0

Females.

Age.	Population.	Deaths.	Rate.
Under 1 year...	3,244,399	2,010	62.0
1 year.....	2,892,390	4,101	141.8
2 years.....	3,169,636	4,014	126.6
3 years.....	3,177,424	3,419	107.6
4 years.....	3,091,757	2,944	95.2
Under 5 years..	15,575,606	16,488	105.9
5–9 years.....	14,112,881	7,533	53.4
10–14 years....	13,587,263	1,828	13.5
15–19 years....	14,352,867	539	3.8
20 years and over.....	89,416,715	1,335	1.5
Ages unknown	.....	18	.....
All ages	147,045,332	27,741	18.9

According to this table, the male death-rate from diphtheria and croup was higher than the female rate at ages under five years; the female death-rate was higher than the male rate at ages 5 to 9 years and 10 to 14 years; the rates for the two sexes were practically the same at 15 to 19 years; and the female death-rate was distinctly higher at ages 20 years and over. When all ages are combined the general death-rate of males from diphtheria and croup is shown to have been 19.6 per 100,000 of aggregate male population, against a female rate of 19.3 per 100,000 of aggregate female population.

The higher female mortality from diphtheria at adult ages finds its most likely explanation in the nursing service of mothers, professional female nurses, etc. The higher mortality rate of diphtheria among boys at ages under five years is explainable as following the general rule that the mortality rate of infant and youthful males is higher than that of females, for almost all causes, with the notable exception of whooping-cough. The sex differences in diphtheria mortality are graphically illustrated in the two accompanying charts, I and V, one on page 447, and the other on page 470.

The steadiness of decline in both the male and female death-rates from diphtheria and croup in the United States registration area, during the last fifteen years, and the uniformly higher male death-rates, with the single exception of the year 1914 are two facts made clear in Table 23.

That the attack-rate of diphtheria and croup follows closely the mortality rate in its sex differences seems to be reasonably certain from the Providence, R. I., statistics.* These, quite exceptionally valuable data, have been

* See Chart I, p. 447.

CHART V.

Mortality from Diphtheria and Croup

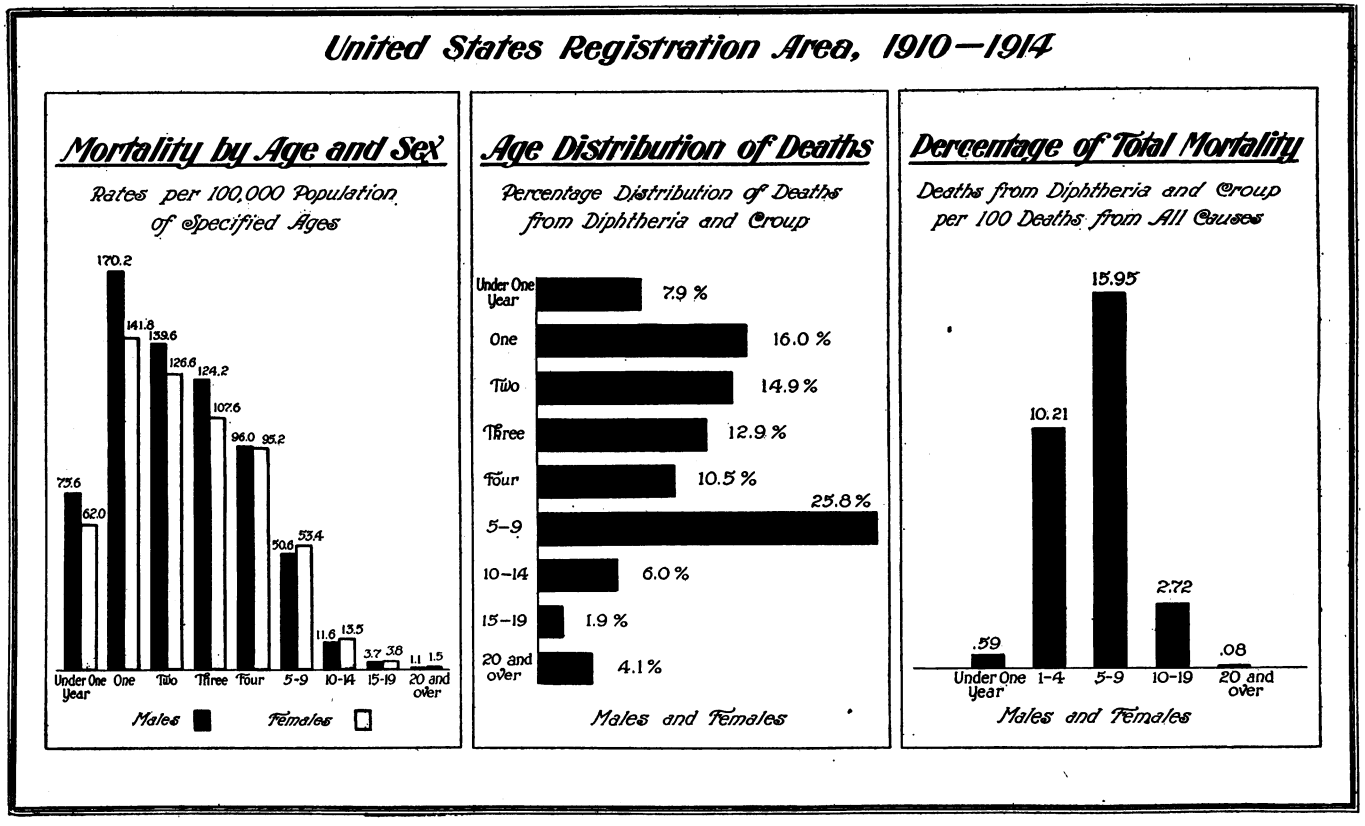


TABLE 23. MORTALITY FROM DIPHTHERIA AND CROUP, WITH DISTINCTION OF SEX, UNITED STATES REGISTRATION AREA, 1900–1914.

Year.	Males.			Females.		
	Population.	Deaths.	Rate per 100,000 population.	Population.	Deaths.	Rate per 100,000 population.
1900	15,415,757	6,749	43.8	15,378,516	6,565	42.7
1901	15,742,434	5,346	34.0	15,628,518	5,321	14.0
1902	16,111,848	5,067	31.4	15,917,967	4,792	30.1
1903	16,489,113	5,310	32.2	16,211,970	5,053	31.2
1904	16,856,270	4,827	28.6	16,492,867	4,617	28.0
1900–04	80,615,422	27,299	33.9	79,629,838	26,348	33.1
1905	17,274,352	4,041	23.4	16,820,253	3,998	23.8
1906	21,322,133	5,624	26.4	20,661,286	5,169	25.0
1907	21,899,144	5,329	24.3	21,117,846	4,825	22.8
1908	23,876,529	5,251	22.0	22,913,384	4,801	21.0
1909	26,020,431	5,382	20.7	24,850,087	4,976	20.0
1905–09	110,392,589	25,627	23.2	106,362,856	23,769	22.3
1910	27,606,526	5,971	21.6	26,237,370	5,550	21.2
1911	30,463,411	5,874	19.0	28,812,566	5,390	18.7
1912	31,128,193	5,684	18.3	29,298,940	5,329	18.2
1913	32,607,069	6,213	19.1	30,691,649	5,707	18.6
1914	33,984,487	6,021	17.7	32,004,808	5,765	18.0
1910–14	155,789,686	29,673	19.0	147,045,333	27,741	18.9
1900–14	346,797,697	82,599	23.8	333,038,027	77,858	23.4

compiled for an eighteen-year period, 1896 to 1913, and are presented in Table 24.

The higher diphtheria attack-rate of exposed females as compared with exposed males is quite pronounced at all ages above five years and the higher attack-rate of males is equally pronounced in the first four years of life.

Age.

William Farr as early as 1861 wrote as follows: "In its age incidence diphtheria is very different from croup, which attacks chiefly children of one, two and three years of age, the boys dying in greater numbers than the girls."* In 1894 Thorne stated as follows: "Age affects the deaths in a very remarkable manner, as is shown by the Registrar-General's reports. Taking the proportion of deaths per 100,000, the deaths at different ages under 10, vary from 34 to 70. The moment you pass 15 years of age a change comes, and after 25 years, instead of rates reaching 43, 70, 64 and 70, respectively, they drop to 2, 2, 1, 2

* Registrar-General's Report, Vol. XIV (1861), p. 217.

TABLE 24. DIPHTHERIA ATTACK-RATE, BY AGE AND SEX, PROVIDENCE, R. I., 1896–1913.—PRIMARY CASES DEVELOPING IN FAMILIES WHERE DIPHTHERIA BACILLI WERE FOUND.

Ages.	Males.			Females.		
	Number exposed, including cases.	number of cases.	Attack-rate per 100 exposed.	Number exposed, including cases.	Number of cases.	Attack-rate per 100 exposed.
Under 1 year....	559	63	11.3	503	47	9.3
1 year.....	533	157	29.5	528	129	24.4
2 years.....	643	256	39.8	577	200	34.7
3 years.....	653	237	36.3	643	208	32.3
4 years.....	713	262	36.7	711	263	37.0
5–9 years.....	3,112	1,071	34.4	3,217	1,210	37.6
10–14 years	2,064	400	19.4	1,984	480	24.2
15–19 years	1,144	127	11.1	1,132	165	14.6
20 years and over	7,283	249	3.4	8,172	416	5.1
Total.....	16,704	2,822	16.9	17,467	3,118	17.9

and so on. Indeed after 25 years of age, diphtheria is a disease which is very little fatal in this country (England). And, more than this, the deaths from diphtheria over that age occur to an important extent among those who are brought into contact with the sick, such as nurses, mothers, and medical men. The greatest age incidence of the disease is between 3 and 10 years of age."*

The mortality statistics of diphtheria and croup have already been presented at some length, with particular reference to their correlation with the sex factor. In the statistics already presented it is clear that in this country as in England and Wales and elsewhere the death-rate from diphtheria is highest at ages 1 to 4 years. The rate drops rapidly after the fifth year of life and it remains low throughout the adult period of life. These facts are most clearly brought out in Table 22, giving the death-rates for the registration area of the United States, by Sex and Age, p. 469.

In Table 25 the attack-rates, by ages of persons known to have been exposed to diphtheria are compared with similar attack-rates of persons known to have been exposed to scarlet fever in the city of Providence, R. I.

The table shows quite a striking similarity in the attack rates of the two diseases at ages under 3 years, then the scarlet fever rates remain higher up to 20 years, at least, when the diphtheria death-rate gains quite a marked ascendency.

The comparatively low mortality from diphtheria in the first year of life has been noted by many writers from

* The Etiology, Spread and Prevention of Diphtheria, by R. Thorne Thorne, *Journal Sanitary Institute*, April, 1894.

TABLE 25. ATTACK-RATES, BY AGE, PERSONS EXPOSED TO DIPHTHERIA AND SCARLET FEVER, PROVIDENCE, R. I., 1889–1913.

Ages.	Diphtheria.			Scarlet Fever.		
	Number exposed.	Number of cases.	Percentage attacked.	Number exposed.	Number cases.	Percentage attacked.
Under 1 year....	1,612	263	16.3	1,560	283	18.1
1 year.....	1,533	657	42.9	1,421	579	40.7
2 years.....	1,810	991	54.8	1,754	970	55.3
3 years.....	1,901	1,055	55.5	1,949	1,229	63.1
4 years.....	1,952	1,095	56.1	1,859	1,240	66.7
5–9 years.....	8,751	4,323	49.4	8,995	5,619	62.5
10–14 years	5,543	1,725	31.1	5,009	2,047	40.9
15–19 years	3,235	593	18.3	2,761	625	22.6
20 years and over	21,882	1,609	7.4	18,219	833	4.6
Total.....	28,219	12,311	25.5	43,527	13,425	30.8

Bretonneau * in 1859 to Rolleston † in 1916. In Rolleston's practice in London, Eng., out of 2,600 consecutive cases of diphtheria only 20, or less than 1 per cent. were in the first year of life. In the Metropolitan Asylums Board's Hospitals, London, the percentage of cases in the first year of life has varied from 1.5 to 2.8 during the period 1888 to 1914. In Providence, R. I., the attack-rate of exposed persons, aged under 1 year, averaged only 16.3 per cent. against an attack rate of 42.9 per cent. in the second year of life. There have been many theories to account for this apparent immunity but there are exceptions to all of them. From analogy with other diseases of infancy and from statistics of breast-fed infants as compared with the artificially fed, the weight of evidence would seem to favor the theory that diphtheria immunity is favored by breast feeding. A special investigation in Boston revealed the fact that out of 20 deaths of infants from diphtheria all but three were bottle fed. The other three were all Italian children.‡

In the following table the distribution by age of the total deaths from diphtheria and croup in the registration area of the United States during the three years, 1910 to 1912, is compared with the similar distribution of the scarlet fever deaths.

It is shown that nearly eight per cent. of all the deaths from diphtheria occurred at ages under one year, against about five per cent. for scarlet fever. It must be remembered, however, that the case fatality of diphtheria is quite exceptionally high at all the early ages and particularly so at ages under one year. In London, during the five years, 1910 to 1914, the case

* Memoirs on Diphtheria, New Sydenham Society, 1859.

† Diphtheria in the First Year of Life, *American Journal of Diseases of Children*, July, 1916.

‡ Trans. 15th International Congress on Hygiene and Demography, Vol. VI, p. 187.

TABLE 26. COMPARATIVE MORTALITY FROM DIPHTHERIA AND CROUP AND SCARLET FEVER, BY AGE AT DEATH, REGISTRATION AREA, U. S., 1910–1912.

Ages at death.	Diphtheria and croup.		Scarlet fever.	
	Number of deaths.	Distribution on basis of 1,000 deaths, all ages.	Number of deaths.	Distribution on basis of 1,000 deaths, all ages.
Less than 1 day	3	0.1	3	0.2
1 day	8	0.2	3	0.2
2 days	12	0.4	4	0.3
3 to 6 days	36	1.1	4	0.3
Less than 1 week	59	1.8	14	0.9
1 week	66	2.0	18	1.2
2 weeks	70	2.1	13	0.8
3 weeks but less than 1 month	58	1.7	14	0.9
Less than 1 month	253	7.5	59	3.8
1 month	167	5.0	20	1.3
2 months	131	3.9	24	1.5
3 to 5 months	403	12.0	115	7.4
6 to 8 months	644	19.1	209	13.5
9 to 11 months	1,045	31.0	335	21.6
Under 1 year	2,643	78.4	762	49.1
1 year	5,438	161.4	1,725	111.1
2 years	5,069	150.4	2,236	144.0
3 years	4,469	132.6	2,139	137.7
4 years	3,477	103.2	1,622	104.4
5 to 9 years	8,549	253.7	4,353	280.3
10 to 19 years	2,671	79.3	1,756	113.1
20 years and over	1,378	40.8	937	60.3
Total, known ages	33,694	1,000.0	15,530	1,000.0

fatality percentage of males aged under one year was 23.9 and for females 28.5; in the second year of life the percentages were, males, 19.6, and females, 20.8; in the third year of life the case fatality had dropped to 11.3 per cent. for males and to 12.3 per cent. for females. With advancing age the case fatality rates decline rapidly in diphtheria just as this is the case in measles, whooping-cough and scarlet fever.

The principal facts relating to age as a factor in diphtheria are set forth graphically in Charts I and III, pages 447 and 470.

Complicating Diseases.

There are so many interesting points in diphtheria mortality and morbidity that it would be hopeless to attempt to deal with all of them, even briefly, in a single paper. The question of complicating diseases is too important, however, to be entirely left out of ac-

count. Perhaps this feature has been best recorded statistically in the annual reports of the Metropolitan Asylums Board, London. In the following table are presented exceptionally interesting data for 49,308 completed cases of diphtheria treated in the Metropolitan Asylums Hospitals during the ten-year period, 1905 to 1914. Albuminuria was a complicating factor in one-fourth of the cases and paralysis in one-eighth of the cases. Other comparatively frequent complications were otitis, scarlet fever, adenitis, bronchopneumonia, lobar pneumonia, measles, chickenpox, nephritis and whooping-cough.

In the Industrial mortality experience of the Prudential Insurance Company of America during the two years 1914 and 1915 the secondary complications were as exhibited in Table 28, p. 476.

Heart diseases are shown to have been by far the most important, numerically, of the secondary complications, totalling 296. Respiratory diseases were complicating factors in 277 cases; scarlet fever in 121 cases; urinary diseases in 98 cases; and measles in 51 cases.

Diphtheria was itself a secondary complicating cause in only six cases in this same experience. In four of these cases typhoid fever was the primary cause and in two cancer was the primary cause.

TABLE 27. INCIDENCE OF COMPLICATIONS AMONGST COMPLETED DIPHTHERIA CASES, 1905–1914. METROPOLITAN ASYLUMS BOARD, LONDON, ENG.

Complications.	Number.	Number per 1,000 diphtheria cases.
Albuminuria	12,369	250.9
Paralysis	6,135	124.4
Otitis	2,371	48.1
Scarlet fever	2,203	44.7
Adenitis*	1,658	33.6
Bronchopneumonia	593	12.0
Measles	436	8.8
Relapse of disease	419	8.5
Chickenpox	347	7.0
Nephritis	299	6.1
Pneumonia, lobar and unqualified	225	4.6
Whooping-cough	202	4.1
Rubella	106	2.2
Mastoid abscess	56	1.1
Mumps	36	0.7
Tonsilitis	11	0.2
Erysipelas	10	0.2
Jaundice	3	0.1
Tuberculosis	2	0.1
Bronchitis	1	0.0
Enteric fever	1	0.0
Influenza	1	0.0
Stomatitis	1	0.0
Total complications	27,485	557.4
Total completed cases	49,308	.....
*Adenitis	1,658	33.6
Suppurative adenitis of acute stage	176	3.6
Suppurative adenitis of convalescence	230	4.7
Simple adenitis of convalescence	1,252	25.3

General Conclusions.

Diphtheria as a cause of sickness is perhaps as prevalent today from the viewpoint of its world-wide distribution as it has ever been in the past. There is reason to believe that it is still spreading geographically and tending to become endemic in the more remote sections of the earth.

Antitoxin is the principal curative agent and its value will increase as the technique of its use is improved and its administration becomes more prompt and universal. There is much

TABLE 28. DIPHTHERIA MORTALITY, INDUSTRIAL MORTALITY EXPERIENCE, THE PRUDENTIAL INSURANCE COMPANY OF AMERICA, 1914–1915.—INCIDENCE OF SECONDARY COMPLICATIONS.

Diseases.	Total.	Under 5 years.	5–9 years.	10–19 years.	20 years and over.
Uncomplicated	2,834	1,406	1,081	261	86
Smallpox	1	1	..	..	..
Measles	51	40	9	2	..
Scarlet fever	121	62	38	15	6
Whooping-cough	12	9	2	..	1
Influenza	3	3	..	..	..
Dysentery	2	1	..	..	1
Erysipelas	1	..	..	..	1
Other epidemic diseases	1	..	1	..	..
Septicemia	19	6	11	2	..
Tuberculosis	3	..	..	1	2
Pott's disease	1	..	..	1	..
Acute rheumatism	2	..	2	..	..
Diabetes	1	..	..	..	1
Leukemia	1	..	..	1	..
Anemia	1	1	..	..	..
Other general diseases	6	2	3	..	1
Encephalitis	2	1	1	..	..
Meningitis	5	1	3	..	1
Cerebrospinal meningitis	2	2	..	..	..
Cerebral hemorrhage	1	1	..	..	..
Paralysis	18	8	8	1	1
Convulsions	5	3	2	..	..
Neuralgia-neuritis	4	2	1	1	..
Other nervous diseases	1	1	..	..	..
Diseases of ears	1	..	..	1	..
Pericarditis	2	2	..	..	..
Acute endocarditis	230	65	123	33	9
Organic heart diseases	62	17	23	13	9
Angina pectoris	2	..	1	1	..
Disease of arteries	1	1	..	..	..
Embolism	2	..	2	..	..
Disease of lymphatic system	3	2	1	..	..
Other circulatory diseases	5	3	1	1	..
Diseases of nasal fossae	1	..	1	..	..
Diseases of larynx	20	8	12	..	..
Acute bronchitis	8	6	2	..	..
Chronic bronchitis	2	..	1	1	..
Bronchopneumonia	170	133	30	7	..
Pneumonia	54	33	15	3	3
Pleurisy	2	..	..	1	1
Pulmonary congestion	19	9	5	3	2
Asthma	1	..	1	..	..
Diseases of mouth	2	2	..	..	..
Diseases of pharynx	25	7	10	7	1
Diseases of stomach	7	1	5	1	..
Diarrhoea-enteritis	20	10	6	2	2
Appendicitis	2	..	1	..	1
Hernia	1	..	1	..	..
Other Intestinal diseases	3	2	1	..	..
Liver diseases	1	1	..	..	..
Peritonitis	1	1	..	..	..
Acute nephritis	56	16	31	9	..
Bright's disease	40	10	22	6	2
Other kidney diseases	2	1	..	..	1
Diseases of uterus	1	..	..	1	..
Other accidents of labor	1	..	..	..	1
Acute abscesses	4	..	1	2	1
Diseases of bones	2	..	1	1	..
Senility	1	..	..	..	1
Ill-defined organic diseases	2	2	..	..	..
Sudden death	1	..	1	..	..
Not specified or ill-defined	65	17	30	14	4
Totals	3,920	1,899	1,490	392	139

evidence that if quicker positive diagnosis can be had antitoxin will become a much more powerful curative weapon than it now is in most of the cities, towns and rural areas of the world.

The specific cause of diphtheria being well known and a curative agent having been discovered it now remains to find some practical means of removing or effectually opposing the underlying conditions favorable to the spread of the disease. The Schick test has made it possible to readily detect persons susceptible to the Klebs-Loeffler bacillus and the temporary immunization of exposed persons by preventive dosage with antitoxin is probably the most important recent development in the scientific efforts to prevent the spread of diphtheria.

Finally, however, it must be admitted that many of the possibly very important underlying conditions favorable to the development and spread of diphtheria are not well understood, if known at all. The comparative importance of temperature, rainfall, altitude, drainage, etc., the possible variations in the virulence of the diphtheria germ under varying conditions of time and place are among the factors which require more extensive research than has thus far been possible. In these inquiries the statistical method is likely to prove a helpful supplement to the methods and work of the bacteriologist and pathologist.

THE PRESENT STATUS OF THE SCHICK TEST.

In an article appearing in the April *Health News* of the New York State Department of Health, entitled "The Present Status of the Schick Test and Active Immunization with Diphtheria Toxin-Antitoxin," by Dr. Abraham Zingher, the author derives the following summary and conclusions:

"1. The testing of children with the Schick reaction on a large scale in the homes, schools and institutions can be readily accomplished, and a permanent record should be kept of the results. From the results which we have obtained, we feel certain that the majority of children, who have passed their second year of life and show a negative reaction, are protected for years and probably for life.

"2. The data that we thus obtain will represent valuable facts, both for the individual and the community.

"3. For the individual the assurance of an immunity to diphtheria will be of great value. If susceptible, he can be actively immunized with three injections of toxin-antitoxin. Schick retests should subsequently be made to determine the success of the protection obtained.

"4. For the community, with an increasing knowledge of the number of permanent immunes, and the selection and immunization of the susceptible ones, we may finally be able to control a disease which continues to be one of the big issues of preventive medicine. The failure so far has been made especially evident by our attempts to deal with the problem of the bacillus carrier. It will probably not be by the elimination of the bacillus carriers, but rather by the active and possibly permanent immunization of the susceptible individuals in a community that we will prevent fresh cases of infection and, to some extent at least, the development of new foci for the dissemination of virulent diphtheria bacilli."